The LANS-alpha Turbulence Parameterization in Ocean-climate Modeling

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Ocean-climate models are typically run at low resolution (1 deg., or 100 km grid cells) in climate simulations due to the computational requirements of the coupled components and duration of the simulations. This resolution is well above the Rossby radius of deformation over most of the ocean, the typical horizontal size of eddies in the ocean. As a result, ocean-climate simulations only include the mean, large-scale flow, but not the eddies that occur in ocean observations (Fig. 1). These eddies affect the mean circulation by transporting heat, salinity, and kinetic energy.

The goal of turbulence modeling is to capture the effects of small scale structures on the large-scale flow. The Lagrangian-averaged Navier-Stokes alpha (LANS-alpha) model, developed in part by Darryl Holm, is a turbulence parameterization that has been shown to improve turbulence statistics at low resolution. It has previously been tested in turbulent pipe flow, large eddy simulations, shallow water models, and quasigeostrophic models, all with positive results.

We have implemented the LANS-alpha model in the Parallel Ocean Program (POP)[1], a code developed at LANL for climate change simulations. Several new technical challenges had to be overcome in this work, including designing an efficient algorithm that fits into POP's split time-stepping scheme [2], and choosing an efficient and stable smoothing method for the advective velocity [3].

LANS-alpha improves the representation of turbulence in all statistics measured in an idealized channel configuration [4]. Figure 2 shows that POP with LANS-alpha (POP-alpha) produces eddy kinetic energy and vertical temperature profiles that are similar to doubled-resolution simulations without LANS-alpha. This implies a great savings in computational time, as doubling the horizontal resolution requires ten times longer, while adding the LANS-alpha model only takes 30% longer. This should have a large impact in climate change simulations, as the ocean is currently forced to run at low resolution due to the demanding computational requirements of climate models.

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[1] D.D. Holm et al., *Los Alamos Science* **29**, 152-172 (2005).
[2] M.W. Hecht et al., submitted to *J. Comp. Phys.* (2008).
[3] M.R. Petersen et al., *J. Comp. Phys.* (2008), in press.
[4] M.W. Hecht et al., submitted to *J. Phys. A.* (2008).

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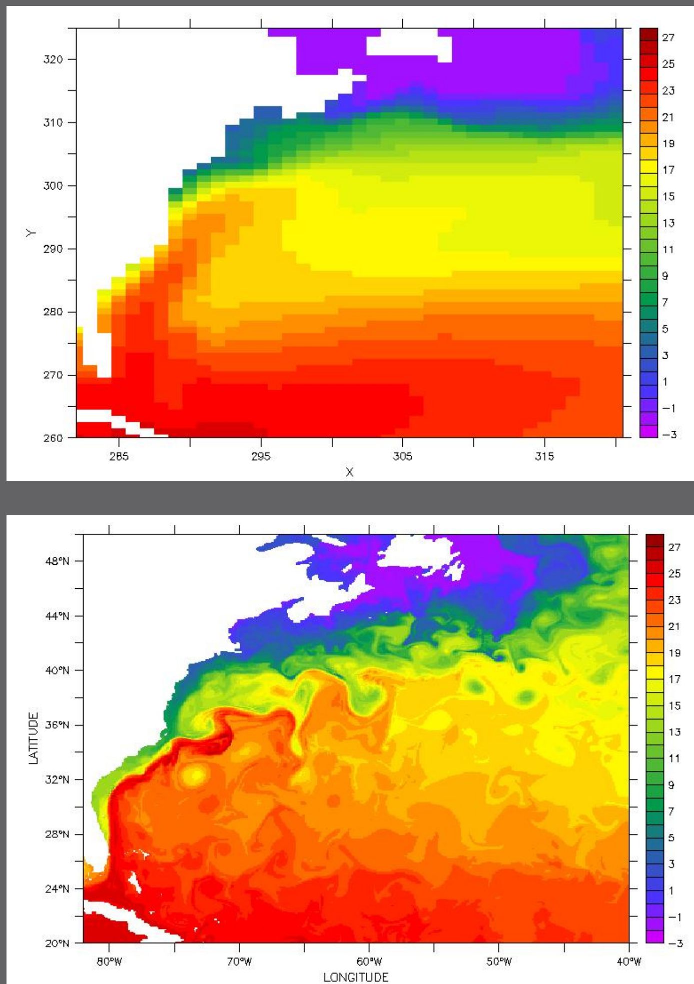

Fig. 1. Surface temperature (in deg. C) of an ocean simulation using a horizontal grid resolution used in climate modeling (1.0 deg., top) and a high resolution ocean simulation (0.1 deg., bottom). Climate model simulations do not resolve the Rossby Radius, and so do not include eddies and their associated turbulent fluxes.

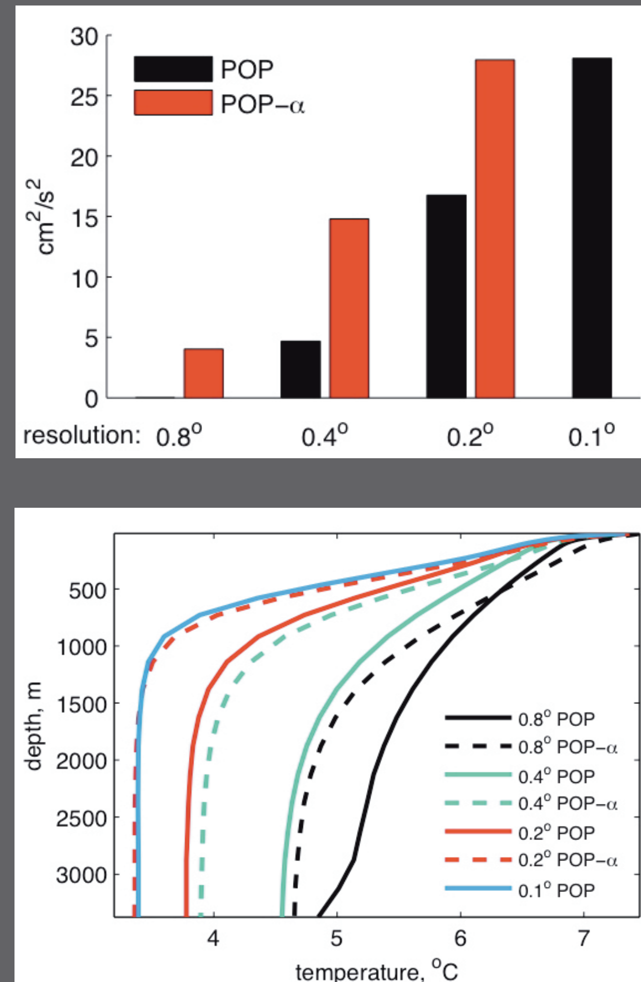

Fig. 2. Comparison of turbulence statistics produced by POP and POP with LANS-alpha (POP-alpha). With LANS-alpha, both eddy kinetic energy (top) and vertical temperature profiles (bottom) resemble doubled-resolution simulations without LANS-alpha. LANS-alpha is an effective turbulence parameterization because it is much cheaper computationally than doubling the resolution.